



driving performance

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EXTENDED REPORT

Pupil dilatation does affect some aspects of daytime driving performance

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Aims: To examine the effects of pupil dilatation on driving performance and determine whether this was related to changes in standard measures of visual function.

Methods: The driving and vision performance of 16 young, visually normal participants was measured with both normal and dilated pupils. Pupils were dilated with 1% tropicamide. Driving performance was measured under daytime conditions on a closed road circuit that was free of other vehicles and has been used in previous studies of driving performance. Measures included road sign detection and recognition, hazard detection and avoidance, gap perception and negotiation, driving reaction times and time to complete the circuit. Visual performance measures included high contrast visual acuity, Pelli-Robson letter contrast sensitivity, and glare sensitivity.

Results: Pupil dilatation significantly ($p < 0.05$) decreased the ability of participants to recognise low contrast hazards and avoid them, decreased their visual acuity and contrast sensitivity and increased glare sensitivity. The decreases in vision performance were not, however, significantly related to the decrement in driving performance.

Conclusion: Pupil dilatation can impair selected aspects of driving and vision performance and patients should be cautioned about these possible effects.

Pupil dilatation is commonly included in clinical examinations, facilitating a thorough examination of both the central and peripheral fundus, particularly for the assessment of diabetic patients. As many patients wish to drive following their eye examinations, there have been concerns raised as to how pupillary dilatation might impact on driving performance and safety,¹ and what advice should appropriately be given to patients. Although there is no documented evidence, many practitioners advise their patients that it will require 4–6 hours for their vision to return to normal following pupil dilatation and to exercise caution or not to drive during that period.² However, there is no objective evidence to suggest that driving is compromised by pupil dilatation. In fact, like other issues that relate to vision and driving, much of the discussion is based upon opinion rather than being evidence based.

A number of survey based studies have recorded patients' perceptions about their vision and driving following pupil dilatation and on the basis of their findings have made recommendations regarding advice to patients. Watts *et al*¹ reported that of a group of patients who reported that they were confident to drive following pupil dilatation, many complained of glare, difficulty with road signs and traffic lights, and judging distances. Watts *et al*¹ recommended the following guidelines: ensure that binocular visual acuity does not drop below 6/10, allow the patient to check their vision against the UK recommended standard, advise subjects to drive only on familiar roads, and allow 30–60 minutes for the patient to adapt to the dilated state. Siderov *et al*³ found that nearly all patients whose pupils had been dilated had a subjective perception of visual disturbance. Half of the participants felt that pupil dilatation affected their ability to drive a car after the eye examination, with increased glare sensitivity being the most commonly cited reason for this perception. Siderov³ concluded that all patients who undergo pupil dilatation as part of an eye examination should be fully informed of the possible detrimental effect on their driving ability.

Only one study to date has actually investigated the effect of dilated pupils on some aspect of driving performance,⁴ and this was undertaken on a driving simulator for a group of young visually normal subjects. This study showed that although pupil dilatation did not lead to a significant decrement in driving performance, it increased reaction times and reduced driving speeds, which led to an improvement in steering accuracy in some subjects.

There is thus a marked absence of studies that have examined the functional impact of pupil dilatation on driving performance, information that is essential in order to provide patients with appropriate advice on driving following pupil dilatation. The aim of this study was to examine the impact of pupil dilatation on a group of young visually normal subjects on a closed road circuit and relate this to changes in visual performance.

METHODS

Participants

The participants were 16 young, white adults who ranged in age from 19 to 24 years (mean 20.9 (SD 1.7) years). All were licensed drivers, in good ocular health, and had distance visual acuities of 6/6 or better with their distance correction. Distance spectacles were worn by six of the subjects, who were all myopic, with the range of spherical equivalents from -0.75 to -6.00 and the range of cylindrical powers from -0.25 to -1.25 . The study was conducted in accordance with the requirements of the Queensland University of Technology human research ethics committee. All participants were given a full explanation of the experimental procedures and written informed consent was obtained, with the option to withdraw from the study at any time.

Participants attended for a series of testing sessions in which the vision and driving measures were conducted with both natural and dilated pupils. Pupil diameter was measured using a millimetre pupil rule. For the dilated pupil condition, one drop of 1% tropicamide was instilled into each eye at least 30 minutes before the testing session. For the

undiluted condition, one drop of saline was administered to both eyes in an identical manner to that of the instillation of tropicamide, in an attempt to minimise participant awareness of the pupil condition. The intertest interval for each participant was between 1–2 weeks and the order of testing was randomised between participants.

Assessment of visual function

Visual acuity was measured using a high contrast (90%) Bailey-Lovie chart, under standard testing conditions. Participants were forced to guess letters even when they were unsure, until a full line of letters was incorrectly read. Each letter seen was scored as -0.02 log units. Letter contrast sensitivity was determined using the Pelli-Robson chart under the recommended viewing conditions. Participants were instructed to look at a line of letters and forced to guess the letter when they were not sure. Each letter was scored as 0.05 log units. An index of disability glare was also determined using the Berkeley glare test³ for the 750 cd/m^2 glare condition. The glare score was derived as the difference in letters seen for the glare and the no glare conditions. For all of the vision measures, participants were tested binocularly, with the refractive correction that they wore for the driving assessment.

Assessment of driving performance

Driving performance was assessed on a closed road circuit which is free of other vehicles and representative of rural roads and has been used in previous studies of vision and driving.^{6,7} The driving assessments were undertaken in sunny conditions between the hours of 7–10.30 am, at approximately the same time of day for each participant. The intertest interval for each participant was between 1–2 weeks and all participants were tested within a 3 month period, hence relatively constant weather conditions were present. Two experimenters were seated in the vehicle to provide route directions, instructions regarding the assessment and to record results. Each participant was given a practice run in order to familiarise themselves with the car, the road circuit and the driving tasks. This was followed by the recorded run where participants were required to drive once around the 5.1 km test route. The practice run was performed in the opposite direction to the recorded run in order to reduce any familiarity effects. Participants wore the spectacle correction that they usually wore for driving. The driving assessment was selected to provide a relatively high degree of complexity and involved tasks of recognition, divided attention, perception, speed of completion, and manoeuvring. For the main test circuit, participants were instructed that they would be required to perform a number of concurrent tasks (see below) and to drive at what they felt was a safe speed, subject to the constraints that they stayed in their own lane, drove within the posted speed limits of the test course, and obeyed all regulatory traffic signs (for example, stop signs).

Road sign recognition

There were 42 standard road signs containing a total of 65 items of information located around the course. Participants were required to report any road signs that they saw as they drove around the circuit. A participant's score was given as the total number of correctly identified items of information.

Road hazard recognition and avoidance

Large, low contrast road hazards were placed at nine locations along the circuit. These road hazards consisted of 1×2.2 metre sheets of 80 mm thick grey foam rubber, so that although participants could feel the hazards when hit, they had a minimal effect on vehicle control. Participants were

asked to report when they saw a road hazard and to avoid it by steering around it. Performance was measured as the number of road hazards reported as seen and the number hit.

Gap perception

This driving task was patterned after one described by Betts *et al.*⁸ Nine pairs of traffic cones, with variable lateral separations, were positioned throughout the test course. The lateral separation between cones was set at one of nine values relative to the outer width of the vehicle's horizontal wheelbase. Six of the cone gaps were wide enough for the driver to pass through and three were too narrow. Participants were instructed to indicate when they saw a pair of cones, estimate whether the clearance was sufficient to permit them to drive between the cones and, if so, to attempt to do so. If they perceived that the cone separation was too narrow, they were instructed to indicate this and drive around the cones. Participants were scored for their accuracy of perceptual judgments by recording the number of correct judgments of gap width, as well as for their ability to manoeuvre through (if they judged the gap wide enough) or around the cones (if they judged the gap to be too narrow) without hitting them.

Divided attention task

To provide a divided attention dimension to the driving task, participants were asked to respond when a target was illuminated while driving around the main test circuit. The targets for this task were five light emitting diodes (LEDs) mounted on the windscreen, at equally spaced intervals at the driver's eye level. The LEDs were linked to the brake pedal via laptop computer hardware and software. Each LED was illuminated three times during the run and participants were instructed to lightly press the brake pedal as quickly as possible whenever any of the LEDs were illuminated. Only a very light tap on the pedal was required to extinguish the LEDs so that it did not affect vehicle control nor time to complete the circuit. The number of LEDs seen was recorded.

Total driving time

An experimenter in the rear of the vehicle recorded the total time taken to complete the main test circuit.

Manoeuvring

Following completion of the main test course, participants were required to manoeuvre in and out of a series of nine traffic cones. The cones were placed on a straight section of the main circuit that was on a slight uphill gradient and were separated by approximately 1.5 car lengths and arranged using lateral offsets. To increase the visual requirements of this task, the contrast of the nine traffic cones was reduced by covering them with a grey cloth of a similar colour to the road surface. Two additional high contrast cones were placed at each end of the low contrast cones and marked the start and finish positions for the task. The course was then performed in the downhill direction. The mean time to complete the course and the mean number of cones hit were recorded.

RESULTS

Table 1 gives the group means and standard errors of the vision and driving measures recorded with dilated and natural pupils. In order to determine whether there were any significant differences in vision or driving performance between the two pupil conditions a series of two tailed paired *t* tests was conducted; the *t* values and significance levels are given in Table 1.

All of the vision measures were significantly worse for the dilated pupil condition compared to the measures under-

Table 1 Group mean and standard errors of the vision and driving performance measured taken under natural and dilated pupil conditions

Test	Mean (SE)		<i>t</i> Test	Significance (two tailed)	Range of differences (dilated-undilated)
	Undilated	Dilated			
Pupil diameter	2.96 (0.12)	6.66 (0.22)	-14.3	0.000	2 to 5.5
HCVA	-0.10 (0.02)	-0.06 (0.02)	-5.84	0.000	0 to +0.1
Pelli-Robson	1.82 (0.02)	1.78 (0.02)	2.33	0.03	+0.05 to -0.20
Berkeley glare	0.19 (0.78)	4.50 (1.09)	-3.12	0.007	-4 to +15
Obstacles seen	8.81 (0.10)	8.06 (0.27)	3.00	0.009	0 to -4
Obstacles hit	0.25 (0.11)	1.19 (0.33)	-3.03	0.008	0 to +4
Correct gap perception	7.19 (0.42)	7.38 (0.43)	-0.59	NS	-3 to 2
Cone gap hit	0.88 (0.26)	1.44 (0.34)	-1.65	NS	-1 to +4
Road signs seen	54.31 (1.63)	54.5 (1.45)	-0.17	NS	+8 to -10
Course time	364.9 (10.2)	376.5 (10.3)	-1.35	NS	-51 to +71
Reaction lights seen	12.00 (0.39)	12.25 (0.38)	-0.47	NS	+4 to -3
Mean man cones hit	0.94 (0.24)	0.72 (0.21)	1.10	NS	-1.5 to +1.0
Mean man cone time	38.15 (3.74)	38.02 (3.54)	0.10	NS	-9 to +14.0

taken with natural pupils. High contrast visual acuity was significantly worse in the dilated compared to the undilated pupil condition, however, the group difference amounted to only two letters, with the greatest individual decrease being one line of letters. Similarly, Pelli-Robson letter CS was significantly reduced in the dilated pupil condition, but again over the group this amounted to only 0.05 log units, equivalent to one letter and the greatest decrease in letter contrast sensitivity was only four letters. Glare sensitivity increased significantly in the dilated condition, accounting for a group difference of four letters.

The only driving measures which were significantly worse under dilated pupil conditions were the number of low contrast obstacles seen and the number hit, where participants saw significantly fewer of the low contrast road obstacles and hit more obstacles under the dilated pupil condition. There was no particular trend in either direction for any of the other measures apart from the time taken to complete the course, where the participants drove more slowly under the dilated pupil conditions, although this increase in time was not statistically significant.

We were also interested to determine whether there was any relation between the changes in driving performance (specifically road obstacle recognition and avoidance) and changes in visual function. An exploratory correlation matrix was established and this demonstrated that none of the changes in high contrast visual acuity, Pelli-Robson letter CS, or glare sensitivity were significantly related to changes in road obstacle detection or avoidance.

DISCUSSION

The findings demonstrated that some aspects of daytime driving performance as measured on a closed road circuit were significantly impaired as a result of pupil dilatation. These related to the ability to detect and recognise low contrast road obstacles and successfully drive around them. These road hazards represent objects that are quite large relative to the resolution limits of the eye and are also of low contrast. This indicates that drivers with dilated pupils are likely to have significant problems with seeing and avoiding such road hazards, which might include potholes, highway debris, real speed bumps, pedestrians, and other vehicles. It is also significant in terms of driving in poor visibility conditions, such as rain or fog, where the contrast of all roadway objects is reduced, and also night-time driving. The only previous studies against which these findings can be compared are those of Potamitis *et al.*,⁴ who didn't include a measure of hazard avoidance. Importantly, their study was

undertaken in a driving simulator where it is difficult to capture the environmental conditions and challenges of normal driving and this may explain their finding that the driving performance of the participants was not significantly impaired under the dilated pupil condition. In particular, the absence of glare in the simulator environment may explain why none of the driving measures appear to be significantly impaired.⁹

The small but significant decrease in visual acuity following pupil dilatation is supported by previous studies,^{4 10 11} although in the study reported here the maximum decrease in visual acuity was one line (logMAR of 0.1 log units), which only occurred in one of the 16 participants tested. Interestingly, O'Connor *et al.*¹² showed that the loss in visual acuity following pupil dilatation was far greater under outdoor conditions (which they termed functional vision), and it is likely that if visual acuity had been tested at the driving track a more substantial decrease would have been recorded. Similarly, although Pelli-Robson Letter CS, was significantly reduced by pupil dilatation, it was only by a minimal amount, being reduced by only one letter over the group; the largest decrease being -0.20 log units, equivalent to four letters. Other studies have similarly found only a small reduction in Letter CS with pupil dilatation.^{4 11} Not surprisingly, glare sensitivity was significantly increased by pupil dilatation and it is likely that this finding underestimates the degree of glare encountered under normal daytime driving conditions, including those encountered on the driving track. Other studies have also found that pupil dilatation increases glare sensitivity¹¹ and suggest that the effects have a significant role in driving performance.

Despite the fact that glare sensitivity and measures of contrast sensitivity are likely to better reflect real driving conditions than high contrast visual acuity, neither predicted the decrease in driving performance associated with the recognition of low contrast hazards and their avoidance. Indeed, it was not possible to predict this decrement in driving performance from any of the vision measures recorded including pupil size, although again, the change in pupil size related to that measured in the laboratory rather than under the driving circuit illumination conditions. It is likely that visual function measured under the conditions of driving (which would include the effects of glare) may have been more representative of the visual decrement for driving that was experienced by the subjects in this study.

In summary, the recommendations from this study are that pupil dilatation can result in impaired daytime driving performance. These changes could not be predicted by

standard measures of visual function undertaken under indoor testing conditions. It is also likely that these results in young adults with normal vision underestimate those in older adults who may have various degrees of lens opacities that can further reduce contrast sensitivity and increase glare sensitivity. Night-time driving, which often occurs when patients have their appointments in the late afternoon, is likely to be compromised further.

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